Troubleshooting in DWDM networks

OPTICKÉ KOMUNIKACE 2013

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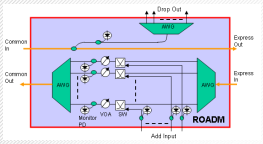
EXFO

Trend: increased network complexity



Mixing modulation formats and data rates on one fiber

Pol mux with non pol mux on one fiber

Coherent networks

New impairments

Crosstalk

Nonlinear effects

Carrier leakage

 # types of failures in DWDM networks

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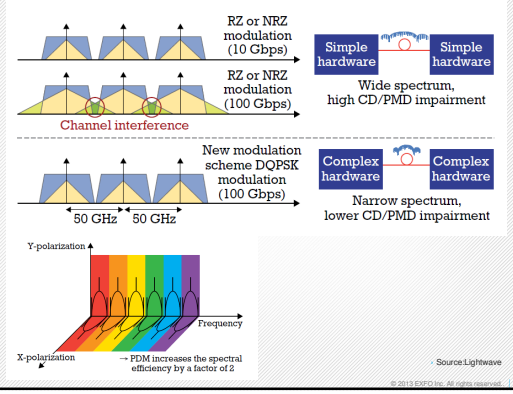
Why new modulation schemes



Source:Lightwave

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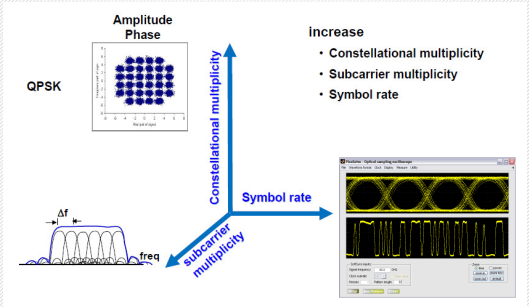
…what are trends in transport networks



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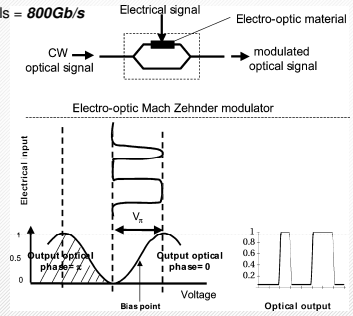
Modulation Schemes Overview

NRZ using a Mach-Zehnder modulator

- ***10Gb/s*** per channel
- ***80*** channels = ***800Gb/s***



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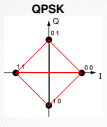
Modulation Schemes Overview

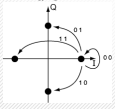
- ***100Gb/s*** per channel (DP)
- ***80*** channels = ***8Tb/s***

QPSK

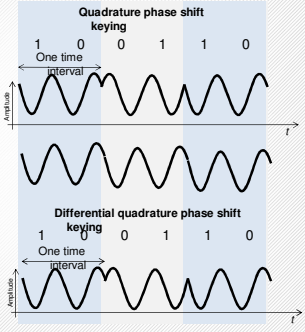


4 phases → 2 bits/symbol

DQPSK



4 phases → 2 bits/symbol



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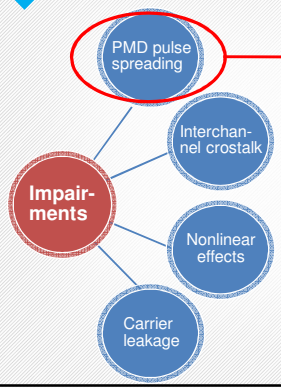
New and “old” impairments in DWDM



- Plain « old » PMD.
- Can now be tested on live noncoherent signals.

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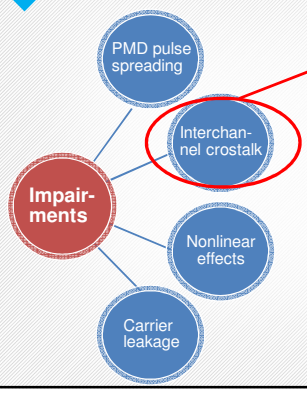
New and “old” impairments in DWDM



- In dense channel plans, when neighbour channels extend within the channel bandpass of a given signal.

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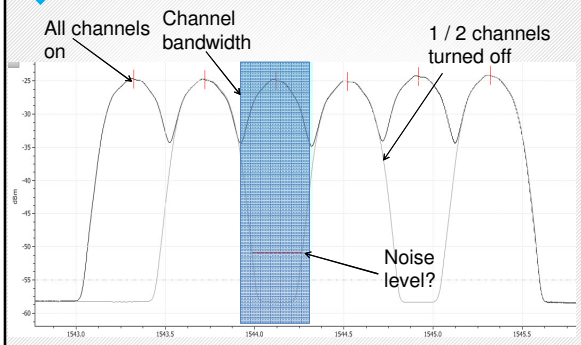
Interchannel crosstalk



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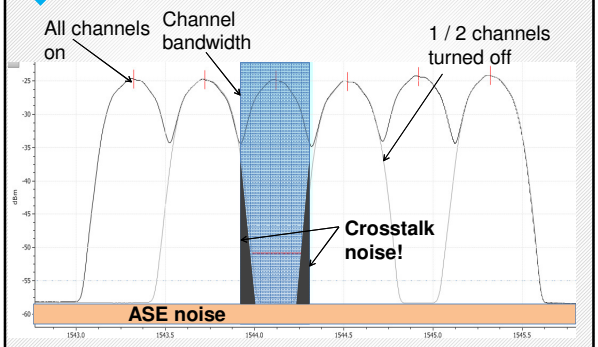
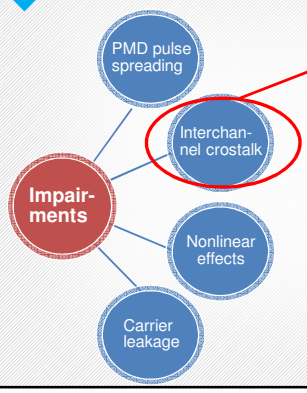
Interchannel crosstalk

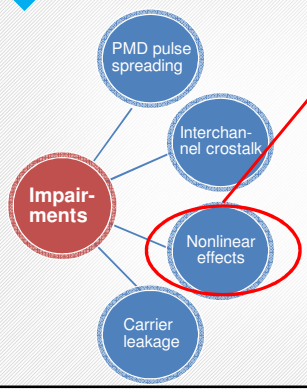


New and "old" impairments in DWDM



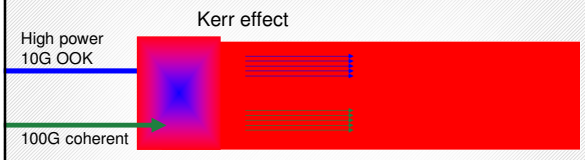
- In dense channel plans, when neighbour channels extend within the channel bandpass of a given signal.
- New impairment at 40G because channel spectral width increases with baud rate.
- Worse with tight channel spacings (≤50 GHz).

New and "old" impairments in DWDM



- New impairment.
- When signals interact nonlinearly with one another
- i.e. cross-phase modulation: phase variation caused by changing power of neighbour channel
- Typical when mixing 10G with 40G or 100G.

Cross-phase modulation



- 10G OOK: amplitude modulation; 40G coherent: phase modulation
- 10G channel goes on and off, changing locally index of refraction as a function of space and time.
- → phase of 100G channel changes. Phase noise! Signal quality degrades.

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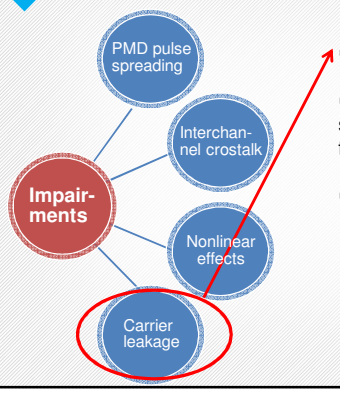
New and "old" impairments in DWDM



- New impairment.
- When CW (unmodulated) signal is present at transmitter output.
- Causes extra noise.

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New impairments: new sources of noise

In summary …

- The old days (10G and below)

$$Noise = N_{ASE}$$

- Today (40G, 100G)

$$Noise = N_{ASE} + N_{NLE} + N_{x-talk} + N_{CL}$$

ASE: amplified spontaneous emission (noise from amplifiers)
NLE: nonlinear effects like cross-phase modulation
X-talk: cross-talk
CL: carrier leakage

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New impairments: new sources of noise

	10G networks	40G and 100G
Noise types	ASE	ASE, NLE, crosstalk, carrier leakage
Noise sources	Optical amplifiers	Amplifiers, fiber properties, neighbour channels, transmitters
Troubleshooting noise issues	Easier	More complex
Troubleshooting procedure for noise issues	Check amplifiers noise figure.	Check amplifiers, channel power (NLE), ch. spacing (x-talk + NLE), transmitters (CL).
Test tools required	Optical Spectrum Analyzers	Improved OSA?

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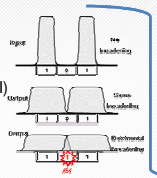
Impact of new and « old » impairments

Impairment

- PMD pulse spreading → Bits that overlap (ISI)



- Interchannel crosstalk → Extra noise from neighbour channel
- Cross-phase modulation → Extra noise due to NLE
- Carrier leakage → Extra noise from transmitter (if PMD)

Worse BER!

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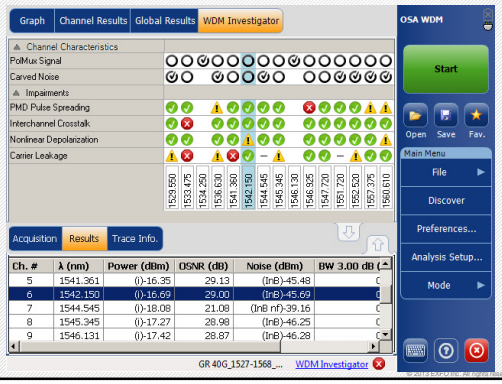
The Solution: WDM Investigator



How to fix these new impairments

- Except for PMD, these are complex impairments to fix, that require an in-depth understanding of DWDM network architecture and configuration.
- At EXFO, we are experts in testing. System design and optimization is the expertise of your NEM.
- Apart from PMD, the right approach should be discussed with you NEM. Below are suggestions only.

- PMD pulse spreading:
  - Test the PMD pulse spreading at different points in the network and pinpoint the fiber span inducing the PMD.
  - Use a distributed PMD analyzer (FTB-5600) to troubleshoot PMD on this span.
  - Use another fiber or another route.
- Carrier leakage
  - Change the transponder at the transmitter side

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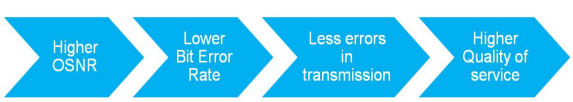
Importance of OSNR



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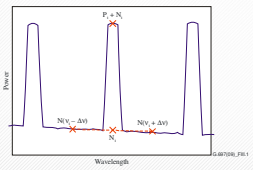
What do the standards say?

ITU-T G. 697 Optical monitoring for DWDM systems, appendix III

"OSNR measurement currently uses the principle of measuring the noise between channels in order to estimate the noise at the channel wavelength."



"This method works well for simple point-to-point systems with nothing but fibre and amplifiers in the optical path."

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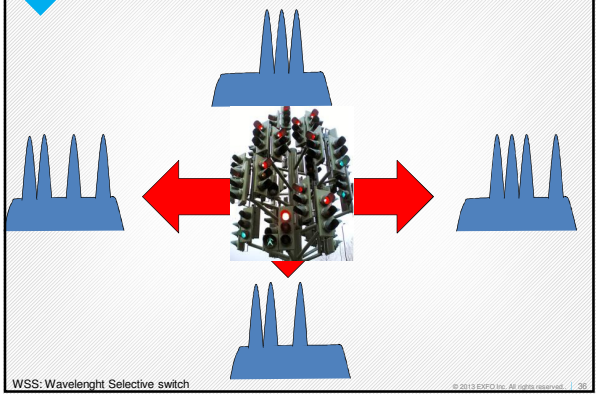
ROADM Definition



WSS: Wavelenght Selective switch

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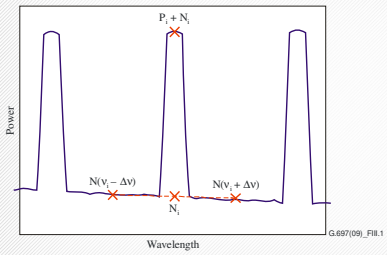
What does the ITU-T say?

ITU-T G. 697 Optical monitoring for DWDM systems, appendix III



"This method works well for simple point-to-point systems with nothing but fibre and amplifiers in the optical path. For more complex DWDM systems, however, *the introduction of any element which causes shaping of the noise between channels renders this method inaccurate*."

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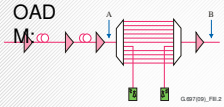
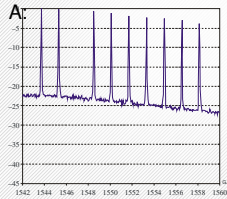
What does the ITU-T say?

ITU-T G. 697 Optical monitoring for DWDM systems, appendix III

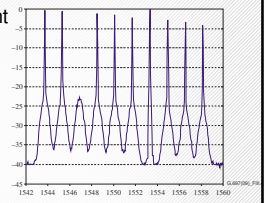
OAD M:



At point A:



At point B:



"The noise between the channels has been strongly shaped by the combined filtering function of the Demux/Mux [...]
At the mid-points between channels [...] the OSNR estimate [...] is about 15 dB optimistic."

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What does the ITU-T say?

ITU-T G. 697 Optical monitoring for DWDM systems, appendix III

"For a realistic OSNR measurement in the presence of noise shaping, it is essential to measure the filtered noise value in the passband of the optical filters in a system (often called 'in-band' OSNR measurement)."

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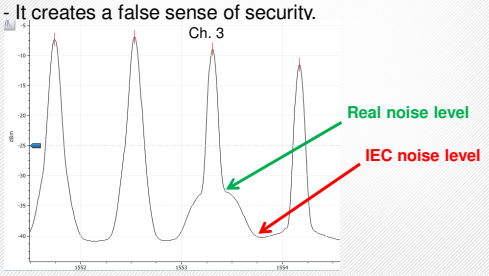
Why traditional OSNR method fails …

Case 1: ROADM is present in the network

- A ROADM contains filters that reduce inter-channel noise.
-The traditional interpolation method leads to an underestimation of the noise.
- It creates a false sense of security.



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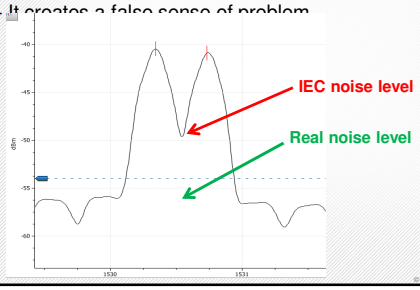
Why traditional OSNR method fails …

Case 2: network operates at 40 Gb/s or more

- At 40G or more, signals are closely spaced and overlap.
-The traditional interpolation method leads to an over-estimation of the noise level.
- It creates a false sense of problem



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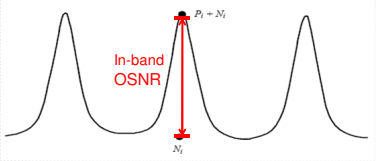
The solution for 40G and ROADM networks

- In-band OSNR : measure OSNR directly at the peak wavelength



- Based on the polarization properties of light:
  - Signal is polarized, noise is unpolarized.
- EXFO's in-band OSNR method: WDM-aware
- For additional details, see white paper « OSNR in Next-Gen Networks » pertaining to FTB-5240S/BP products
  http://www.exfo.com/en/Products/Products.aspx?Id=433

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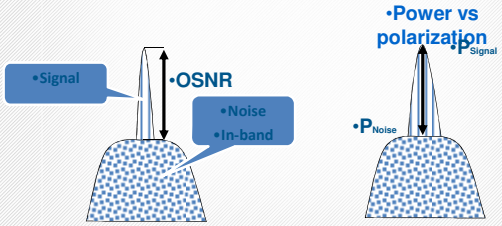
EXFO In-band OSNR Measurement

- Basic assumption: Signal is mainly polarized and noise is mainly depolarized



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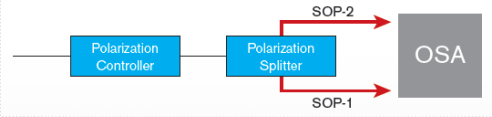
EXFO's WDM-aware Setup

- EXFO OSA comprise a polarization controller at the input and a polarization beam splitter.
- The polarization controller changes the polarization of the input signal (including the noise).
- The polarization beam splitter divides the input in two arms with different states of polarization (SOP).



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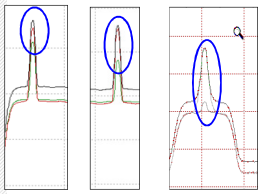
WDM-aware Method

EXFO approach: adjust the polarization controller so that there is at least a 3 dB difference between the peaks in two different scans



- Condition easy to meet.
- All the above peaks are usable
- Then comes the magic…

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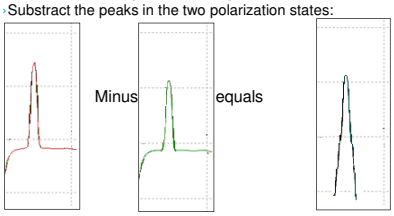
WDM-aware Method

Let's take the first peak as example:

- Substract the peaks in the two polarization states:



- Since the noise is the same in both polarizations, the subtraction removes the noise …

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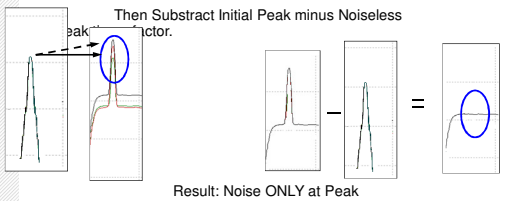
WDM-aware Method

Next step: Multiply this noiseless peak by a factor to make it have the same power as the Initial Peak:

Then Substract Initial Peak minus Noiseless



Position

Result: Noise ONLY at Peak

=> Calculate OSNR

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Advantages of EXFO's approach

- **Very Fast:** usually 3-5 minutes.
- **Very robust** to PMD as it is not necessary to null the signal to obtain some diversity in each arm.
- **Repeatable**,
- Can measure any type of **ROADM filters** as we construct signal and noise traces inside the signal.

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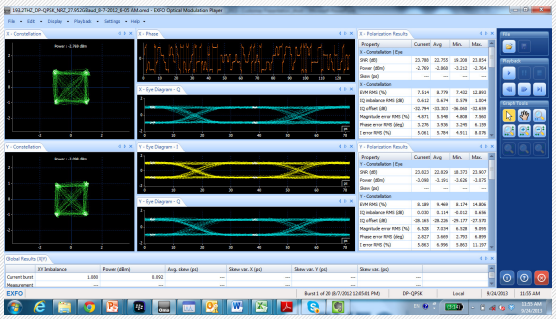
Coherent 40G and 100G: now and beyond



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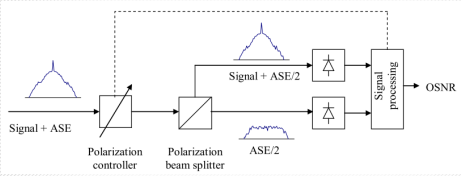
Why in-band fails in coherent networks

ITU-T G.697 Optical Monitoring for DWDM systems

III.1.3 Polarization extinction measurement



For a polarization multiplexed signal, there is a separate signal on each of the two orthogonal polarizations so it is not possible to extinguish the signal using a polarization beam splitter. Hence, it is not possible to use this method of OSNR measurement for these signals.

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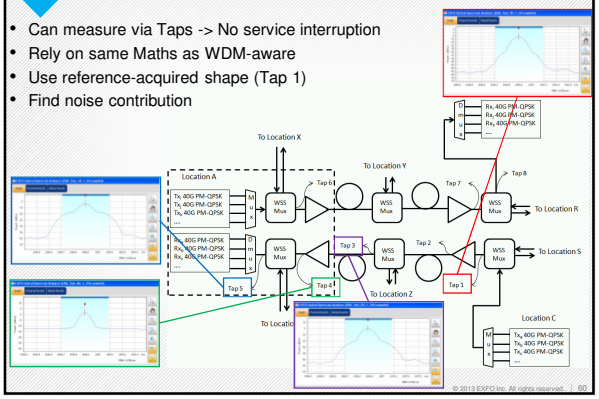
EXFO's approach – Reference-Based

- Can measure via Taps -> No service interruption
- Rely on same Maths as WDM-aware
- Use reference-acquired shape (Tap 1)
- Find noise contribution



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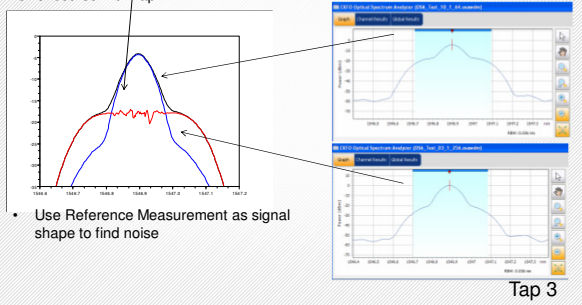
EXFO's approach – Reference-Based

- Showing with Tap 3 to demonstrate reference with residual OSNR but works well of course with Tap 1



- Use Reference Measurement as signal shape to find noise

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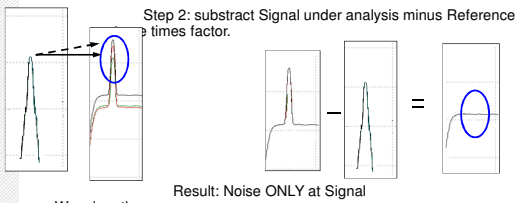
Reference based approach

Step 1: Multiply the reference trace by a factor to make it have the same power as the signal under analysis:

Step 2: substract Signal under analysis minus Reference x times factor.



Result: Noise ONLY at Signal

=> Calculate OSNR

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OSNR methods summary

Data rate	ROADM?	Modulation format	Baud rate	OSNR method
≤ 10 Gbits/s	no	OOK	10 GBd	IEC
≤ 10 Gbits/s	yes	OOK	10 GBd	In-band
40 Gbits/s non-coherent	yes or no	DQPSK or other	20 GBd	In-band
40 Gbits/s coherent	yes or no	DP-QPSK, DP-BPSK	10 GBd or 20 GBd	Pol mux
100 Gbits/s coherent	yes or no	DP-QPSK	28 GBd	Pol mux

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So is pol mux OSNR available for 40G/100G?

EXFO now offers reference-based method :

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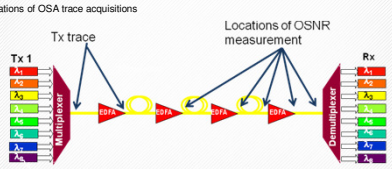
Figure 1. Locations of OSA trace acquisitions



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From 10 to 40 to 100G in the Field

Going faster means more pressure on the network. Or does it…?

Speed	Modulation	OSNR	CD	PMD
10Gbps	NRZ - Traditional On-Off Keying	Traditional OSNR (IEC)	Typically around 1100 ps/nm	Typically around 10ps (average PMD)
40Gbps	OOK, DPSK or DQPSK (non coherent)	Requires In-Band, IEC Fails	Typically around 250 ps/nm	Typically below 10ps (average PMD)
40Gbps	DP-QPSK (Coherent)	Requires Pol-Mux ready In-Band (not yet available?)	60.000ps/nm, but likes residual CD	Typically above 30ps, but sensitive to instantenous DGD
100Gbps	DP-QPSK (Coherent)	Requires Pol-Mux ready In-Band (not yet available?)	20´-40.000ps/nm, but likes residual CD	Typically above 20ps, but sensitive to instantenous DGD

That testing needs varies, but for different reasons

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Questions?

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